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Freshwater Ecology

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Content

Introduction

The Environment

The term "environment" refers to all things around the organism which have a direct influence on the activities of it, i.e. not only the medium and substratum with their diverse characteristics of light, temperature, composition….. etc., but also other plants and animals present, which may provide food or act as parasites, predators, competitors … etc. Thus, an organism's environment consists of two parts: the *physical environment* or non-living environment and the *biotic* or living environment.

The first of the physical features of the environment to be considered is the "*medium*", i.e. the material which immediately surrounds the organism and with which it has its all important exchanges. Some organisms live in soil, some in the sea and some in ponds; some thrive in manure piles, others in the blood or cells of vertebrates … etc. The medium in all these examples, and for organisms in every natural situation, is either a liquid or gas and is usually water or air. Although, plants and animals inhabiting soil or mud may at first appear to be exceptions, a closer look shows that a film of air or water around each organism is actually the material in immediate contact with it. The term "medium" is thus distinguished from the "substratum" or surface on or in which the organism lives.

The existence of air and water as the fundamental media divides the world into two major environments: *terrestrial* and *aquatic*. In this sense the globe is divisible into:

1. *The lithosphere;* which comprises the masses of land.
2. *The hydrosphere;* which comprises the total water mass. Upon the hydrosphere is based the science of *"hydrography"* which includes:
   a) *Oceanography,* that deals with the vast continuous mass of salt water in oceans and seas.
   b) *Limnology,* that deals with the various water units found on earth, most of which are freshwater bodies.

The term limnology is derived from the Greek word ***limne*** meaning pool, marsh, or lake. The science arose from lake investigation, however. It was born on the shores of Lake Geneva, its original description in French **(Forel, 1892).** As time passed, limnology became the science of inland waters, concerned with all the factors that influence living populations within those waters. It now includes study of running water (lotic habitats) as well as of standing water (lentic habitats)

Differences between marine and freshwater environments

1. Volume and surface area:

The total volume and surface area of freshwater on land are very small compared to those of salt water in seas and oceans. The world's total area of inland waters is approximately 5 x 10^6 square kilometers, in contrast to the oceans' 36 x 10^7 square kilometers, which is equal to about 70.8% of the surface of the Earth.

2. Total salt content (salinity):

The salt content of sea water is relatively high and ranges between 35-40%o, while the concentration of soluble salts in most natural fresh waters is only 0.3%o or less as indicated in the following table:

Soft fresh water	< 0.065%o
Hard fresh water	0.3%
Ocean water	35.0%o
Red Sea	40.0%o

Inbetween salt and fresh water there is an intermediate category, which is *"brackish water"*. This is not characterized by a definite percentage of salinity. Natural waters in which the total salt content is lower than that in the sea and higher than in hard fresh water are considered brackish.

3. Chemical Composition:

Sea and fresh waters do not only differ in their total salt contents but also in their chemical composition or kinds of dissolved salts or ions found in them as shown in the following table:

	Na	K	Ca	Mg	Cl	SO_4	CO_3	Total %
Soft fresh water	0.016	-	0.010	-	0.019	0.007	0.012	0.0065
Hard fresh water	0.021	0.016	***0.065***	0.014	0.041	0.025	***0.119***	0.03
Sea water	***10.7***	0.39	0.42	1.31	***19.3***	2.69	0.073	3.49

In sea water, chloride and sodium ions are the first and second most abundant ions, whereas in hard fresh water carbonate and calcium are the

most abundant ones. However, hard fresh water contains more dissolved salts than soft fresh water, particularly with respect to carbonate and calcium ions. In typical fresh water, these ions are relatively less than chloride and sodium.

4. Osmotic Pressure:

Because of the low salinity, fresh water has a *lower osmotic pressure* than sea water. This difference raises problems in maintaining proper water balance between the inside and outside of organisms living in fresh waters.

5. Relative weight and buoyancy:

Because of the same difference in salt content, the relative weight and relative viscosity of fresh water are much lower than of sea water. Therefore, fresh water is less buoyant than sea water and suspended material are thus much more abundant in it.

6. Relative influence of climatic factors:

Fresh water is generally more liable to be affected by climatic conditions than sea water because of the smaller volume and isolation of freshwater bodies as compared to oceans. Freshwater bodies are therefore subject to greater fluctuations in temperature, water volume, dissolved gases, chemical composition, … etc., due to climatic factors.

7. Content of organic material:

Freshwater bodies are relatively richer in putrefying organic material than the sea. Therefore, Oxygen content is always less than that of sea water.

Freshwater environment

Fresh water is deposited on land mainly in the form of rain or snow and tends ultimately to reach the sea. A considerable portion of it, however, goes back into the atmosphere by evaporation, or soaks into the ground to appear elsewhere in springs or to feed ponds, lakes and streams.

Freshwater environments are classified according to the activity or movement of water in them into:

1. Lotic environments (or running-water series): In which the entire mass of water actively and continuously moves in one direction, as in brooks, creeks, streams and rivers.

2. Lentic environments (standing or static-water series): In which the water does not flow continuously in a definite direction. The only water movement in these environments is due to wind and internal currents. This series includes lakes, ponds and swamps.

Lotic Environments

When rainwater falls on an uneven surface it collects in depressions. As water overflows in these depressions, it erodes a narrow channel or ***brook*** downhill which deepens with every succeeding rainfall. Such a tiny brook gradually deepens, widens its bed and increases its length forming a ***creek***, then a temporary ***stream.*** When the stream channel becomes cut below the level of groundwater, the stream becomes permanent as it will be continuously fed with seepage water. Young streams less than *3 meters wide* are usually referred to as *brooks* or *creeks*. Those more than 3 meters wide are often called *rivers*.

A young river is characterized by a narrow channel, steep sides and fast current. It has few tributaries and many water falls, pools and lakes along its course, especially in mountainous lands where water may accumulate in some depressions in the course of the river. But with the continuous filling up of these depressions and the erosion of their outlets, they become gradually obliterated. Thus, as the river matures, its channel becomes wider, its slopes more gentle, its tributaries more numerous and longer and the water flow in it becomes slower.

This lotic series of freshwater environment may thus be genetically expressed as: Source → Brook → Creek → River series. In other words, the direction of evolution is ***towards extension*** of the water body. This evolution of the lotic environments takes place mainly due to physical factors.

The character of the bottom of the water body in this lotic series depends mainly on the velocity of the current. Water flowing at the rate of about 50cm/second is considered swift flowing. It rolls pebbles and rock along the bottom, and carries finer material such as silt, sand and organic matter in suspension. When the elevation gradient is less steep and the water current is slower, gravel is deposited first then sand, but finer material is carried by the water. Only when the current is negligible that suspended material settles down so that silt- or mud-bottom streams are formed.

Lentic Environments

Water from upland runoff, ground seepage, springs and melting snow fields and glaciers collect in depressions and valleys forming lakes. However, natural processes work ***towards extinction*** of these lakes or their

gradual transformation into ponds, then marshes or swamps and eventually dry land, i.e. in the opposite direction to that of the lotic series. The series of lentic environments may be genetically expressed as: Lake → pond → Swamp series. This evolution takes place due to a combination of physical and ecological factors. ***Silting in process:*** various material and sediments are brought into lakes by animals, by wind and by inflowing streams and rain water from adjacent land slopes. These substances build up the shore of the lake and gradually form a marginal shelf on which littoral vegetation start to grow. As the lake grows older, this marginal region increases gradually in area at the expense of the bottom and open water areas.

Meanwhile products of erosion cut away from the exposed shore by wave action, and various organic deposits produced by aquatic plants and animals of the lake, together with products of decay of dead organisms, all become deposited on the lake bottom. The ***lake,*** therefore, becomes gradually smaller and shallower, transforming into a ***pond.***

Plants growing along the margin of the pond gradually push in from shallow water to deep water. Deposits of organic matter and various materials from the surrounding land continue to deposit on the bottom. Rafts of vegetation from the pond margin establish islands in the center of the pond, and these islands grow in size until they meet and also join the shore, thus a pond gradually transforms into a ***swamp*** or ***Marsh.***

Grasses grow allover the swamp area, the soil further builds up and becomes gradually drier, and some shrubs appear on it. Later on certain small trees invade the area and finally large ***forest*** trees dominate it. During this sequential development of communities, the floral and faunal components change as the surrounding environment changes.

The distinction between a lake, a pond and a swamp is not sharp. However, area, depth and vegetation growth are essential elements in this distinction.

Generally, a ***Lake*** is a large body of standing water which is completely isolated from the sea and has a large area of open deepwater, the center of which is deep enough to exceed the limits of growth of such plants that grow on the shore. 2 distinct regions can thus be distinguished in the bottom of the lake:

1. Littoral zone: which extends from the water edge to the lower limit of rooted vegetation. The bottom in this zone may be rock, gravel, sand or mud. This zone may be further divided into:

a) Eulittoral zone; extending between high and low water marks, where the beating of waves are most effective.

b) Sublittoral zone; extending from the lower limit of wave action to the lower limit of rooted vegetation. Floating, submerged and emergent plants may grow over the whole of the littoral zone.

2. Profundal zone: is the entire bottom found below the lower limit of rooted vegetation.

The region of open water above the bottom is known as the *Limnetic zone*. It corresponds to the pelagic region of the sea.

A *POND* is a small shallow lake which has rooted vegetation growing over most of its bottom, i.e. it has no distinct profundal zone as that of a proper lake. Ponds may originate as shallow basins filled with water, as large pools in the course of rivers, or as a result of the filling up of a lake. Young ponds may have rock, sand, clay or mud bottoms. But in mature ponds, there is often a dense accumulation of organic matter and silt. Some

ponds are *temporary* as they are so shallow that they dry up in summer months, while others are permanent.

A *SWAMP* is a pond of such small depth that it is almost completely occupied by emergent vegetation. Some of these vegetations may be terrestrial trees.

A *MARSH* is a swamp with emergent herbs but no trees.

Main differences between lotic and lentic environments

1. Current: The whole volume of water flows in one direction in the lotic series but not in the lentic one.

2. Depth and width: The depth and width of basin are as a rule smaller in the lotic than in the lentic environments.

3. Evolution and succession: The direction of evolution in the lotic series is towards extension, while that of the lentic series is towards extinction. Various communities of aquatic organisms are influenced by this evolution and undergo a conspicuous succession. Thus, communities characteristics of swift-flowing streams are succeeded by others characteristic of slow-flowing rivers, and communities characteristic of a lake environment are succeeded by others typical of ponds and finally replaced by swamp forms.

4. Fate of eroded and suspended material: Materials eroded at any point along the course of a running-water body or suspended in the water at any point are always carried downstream with no opportunity for return. Corresponding materials in standing-water bodies commonly remain within the same basin.

5. Stagnation: constant flowing and mixing of the water in the lotic series usually eliminate prolonged stagnation such as that occurring in deep waters in lakes and some ponds.

6. Ecological conditions: All physical, chemical and biological conditions change along the course of a running-water body so that conditions at the mouth may be quite different from those at the source. No corresponding differences are encountered in the different parts of a standing-water body.

7. Relative influence of climatic factors: The ratio of surface area to water volume is larger in the lotic than in the lentic series due to the relative shallowness of the former. Such larger ratio of surface to volume makes water and living conditions in the lotic series more affected by climatic conditions than in the lentic one.

8. Basic food material: Most lotic environments manufacture within themselves little food material and depend more upon contributions from the surrounding land. But lentic environments continuously accumulate organic detritus in their basins.

Shapes and sizes of lakes (Morphometry)

The methods of measuring and analyzing the physical dimensions of a lake are termed morphometry. Many aspects of the lake's fauna and flora can be studied without this knowledge, but to go into theoretical limnology and to determine some indices of productivity, morphometric data must be known.

The Bathymetric Map and its data:

An outline of the lakeshore, with submerged contours, drawn to scale

is a necessity for calculating morphometric data. Usually such a bathymetric map is easily produced by tracing the shoreline from aerial photographs. An examination of an aerial photo usually reveals landmarks of a way around the lakeshore. From these landmarks one can arrive at a scale by driving an automobile from point to point and noting the final odometer reading to determine the distance. With an outline of the lake and a proper scale, at least 5 bits of information can be deduced about the lake, even before subsurface configuration is known.

Surface dimensions:

(1) Maximum length: The distance across the water between the two most separated points on the shoreline is, of course, the maximum length (l). It can be determined simply from the outline map with a ruler.

(2) Breadth: The width of a lake (b) is determined by measuring at approximately right angles to the axis of maximum length, a line that connects the greatest distance between two opposite points on the shore. The mean width ($\bar{b}$) can be found if the lake area is known; it is the quotient of area divided maximum length.

(3) Surface area: Surface area (A) is an extremely important dimension, because it is at the surface that *solar* energy enters the aquatic habitat. With a map of the lake's outline and an appropriate linear scale, there are at least 4 ways to determine the area. An inexpensive procedure is to draw this outline on graph paper, with the scale of the squares spacing being known. Summing the squares, estimating the fractions thereof, and multiplying by the proper

factor would serve to estimate the lake area.

The polar ***planimeter*** is an instrument designed for deriving areas of flat surfaces. With it the shoreline is traced in a clockwise direction, and dial numbers are read when completed. These dial readings can be compared with the results of tracing a square or circle of known area, and from the map scale the actual lake area can be calculated.

(4) Length of shoreline (L): can be determined from the map by sticking pins in place around the shoreline and connecting them with a thread that can be measured later. A map ***rotometer*** may also be used. This instrument is essentially a wheel and dial that indicates the linear distance the wheel rolls.

(5) Shoreline development index (D_L): is a comparative figure relating the shoreline length to the circumference of a circle that has the same area as the lake. The smallest possible index would be 1.0.

The formula from which the index is derived is $D_L = \frac{L}{2\sqrt{pA}}$.

Although a newly formed lake basin derives its outline from the events that gave rise to it, the shoreline will change with aging. Currents and waves within the lake tend to erode promontories, reducing shoreline irregularities. Protected bays are the first lake parts to fill in and become portions of the terrestrial environment. As the bays are eliminated and irregularities are removed by events occurring within the lake itself, D_L values are *reduced.* Conversely, the arrival of sediments by an incoming stream might result in a delta projecting into the lake. If part of the delta eventually emerges as water level lowers, it contributes more irregularity to the shoreline and, perhaps, increases in D_L index.

The development of shoreline may play some role in determining the trophic nature of the lake because shallow water is the most productive. Most photosynthesis occurs in the upper, illuminated layer of a lake. Furthermore, in this upper zone near shore, there is a proximity to the decomposition products from the bottom sediments that cannot be equaled in off shore regions. Moreover, the arrival of *terrestrial nutrients* to the lake is, to a great extent a *shoreline function*. It is tempting to theorize that, if two lakes alike in most features except shoreline development, the one with the highest D_L would be more productive.

Subsurface dimensions

Contour mapping: to this point, morphometric data have been derived entirely from an *outline* map drawn to scale. Subsurface contours must be established and plotted before the bathymetric map is complete and before one can proceed with other morphometric work.

There are several methods of finding depths and their positions within a lake. With echo-sounding equipment, it is possible to move by boat from one landmark to another, keeping the speed constant and timing the entire journey. Time intervals are assumed to be proportional to linear spacing for the purpose of plotting depths along the transect. Echo-sounding devices permit the rapid accumulation of many depth data. A matrix of points will eventually appear on the map and *contour lines* can be ploted by interpolation or by computerized programs. In small lakes a contour interval of 1 or 2 meters may be appropriate. In large lakes the contour lines may be shown at 5 or 10 m intervals.

Maximum depth: Depth is indicated by the symbol Z. Thus Z_o is the

surface, a depth of zero; its contour is the shoreline. A parameter of popular interest, the maximum depth, Z_m, should be found. This is the datum most people search for after in studies of Lake Dimension.

Mean depth ($\bar{Z}$): The lake volume divided by its surface area obviously will yield the mean depth ($\bar{Z} = \frac{V}{A}$). Mean depth has been considered an important dimension since Thienemann (1927) proposed that in German lakes a boundary between what he defined as oligotrophy and eutrophy lay at about 18m. Lakes with $\bar{Z}$ greater than 18m showed features he had assigned to oligotrophy; shallower lakes were more productive and belonged to the eutrophic series.

Cryptodepressions : Frequently the maximum depth of a lake is below sea level; the portion of the basin beneath sea level is called a cryptodepression (Z_c). For example, if a surface of a lake lies 116m above mean sea level; its maximum depth is 133m; and by subtraction, it has a Z_c of 17m. The surface of the saline Dead Sea is 399 m below sea level; therefore, its entire basin is a cryptodepression.

Volume (V) : The volume of a lake can be calculated when the area circumscribed by each *isobath* is known. One method involves formulas such as the following :

$$V_{Zo-Z1} = 1/3\ (A_{Zo} + A_{Z1} + \sqrt{A_{Zo} \times A_{Z1}})\ (Z_o - Z_1)$$

From this, the volume of water between the shore line contour (Zo) and the first subsurface contour (Z_1) is found. A_{Zo} is the total area of the lake, and A_{Z1} is the area limited by the Z_1 line. If the values are at 2m intervals, the value of Z_o - Z_1 would be 2m. Volumes of succeeding strata are now determined one by one and summed, giving eventually the total number of cubic meters of water within the lake (volume of the lake).

Hypsographic curves: An easier method of computing V is to construct a curve on graph paper. The area bounded by each contour line has been plotted against the depth of that contour. The area beneath the curve designates volume. The hypsographic curve provides many other data as well. For example, volume at any stratum in the lake can be computed. A horizontal line from any point on the curve intersects the vertical axis to show the area inside a contour drawn at that depth. Also, the area at each depth, its percentage of the total area, the volume of each stratum and the percentage of the volume contained in each stratum; all these useful data can be obtained from the depth-area curve of the lake.

Uses of morphometric data

If a particular body of water is to be studied in detail, the results of all morphometric procedure should be kept on record for future use. These data will be useful in faunal, floral, and productivity studies. Some specific examples follow :

- The accepted manner of expressing amounts of *bottom fauna* is numbers or grams per square meter.
- The total number of animals in the profundal zone can be calculated by knowing, first, the numbers of animals per unit area of all strata then, multiplied by the total area of every stratum.
- If we know the amount of *oxygen* per litre produced per hour within each stratum, we can find the total produced within the stratum by multiplying its volume by oxygen value. With summation, the total amount of O_2 produced within the lake during a certain period of time is revealed. If the sum is divided

by the surface area, *photosynthetic rate* can be derived expressed as grams of O_2 per square meter per hour.

- This method can be applied to many other data, to mass or numbers of phankton organisms, to iron or sulfate, or to whatever is being measured and studied.
- *The Morphoedaphic index (MEI)* : It has been used extensively during the past decade to obtain first order estimates of *fish yield potential* for freshwater system. MEI, as proposed by Ryder (1965), is the ratio of total dissolved solids to mean water depth " $\overline{z}$ ". The relationships of fish yield to MEI for many lakes were plotted and a regression line was performed. Theoretically, the most favorable index being about 40.

Ecological Factors

The environment, as mentioned above, is a complex of many elements or factors : physical, chemical and biological factors. A knowledge of the influences of all these factors and of the responses of different organisms to them is essential for understanding the different biological phenomena noticed in any freshwater environment. The fact that certain plants or animals have a limited range of *distribution* or are found only in specific habitats can be understood if their behaviour could be related to these different ecological factors. The factor that first stops the *growth* or spread of the organism is called the "Limiting factor".

Since ecological factors have such an important role in controlling the distribution of plant and animal life as we know it today, it would be interesting to review the ways in which physical, chemical and biotic factors affect the lives of the flora and fauna of freshwater environments.

A. PHYSICAL FACTORS

1. Temperature

Temperature is perhaps the most familiar ecological factor and is probably also the one which has the most pronounced effects on living organisms.

Temperature extremes in aquatic environments :

Radiation from the sun is the only important source of heat for natural waters. This heat is absorbed by water at far higher rates than by air. In air, an average decrease of about 1°C occurs every 150 metres of altitude. But in water, solar radiation is largely absorbed by the surface layers, and the cooling of water by radiation or evaporation also takesplace at the surface strata. Heat is transferred to deeper layers mainly by movement of the water itself or by vertical circulation, not by conduction or radiation from one layer to another.

Temperature extremes on land are also quite different from these found in aquatic environments. While the temperature on land may fall for below 0°C and reach high levels in hot seasons, the temperature of open water in aquatic environments does not fall below the freezing point. In freshwater bodies the water temperature never falls below 0°C, and in oceans it seldom reaches -2.5°C. The maximum temperature recorded in the ocean is usually 36°C, and in small pools and littoral regions of freshwater bodies the temperature may go somewhat higher. Thus the whole range of temperature in the sea and in most freshwater habitats is within the limits of tolerance of aquatic plants and animals.

Seasonal changes in water temperature in freshwater environment

Freshwater attains its maximum density at 4°C. Thus, any warmer or cooler water will float on top of water at that temperature.

In lakes, there occurs a distinct annual temperature cycle which is closely associated with the 4 seasons of the year. ***The annual temperature cycle in a temperate lake during the course of a year has the following features :***

In winter : As the surface water cools, it becomes denser, sinks and becomes replaced by the warmer water below it. This process goes on until the temperature of he water throughout the lake is reduced to 4°C. When the surface water further cools below 4°C, it no longer sinks but remains on top while its temperature continues to fall until a layer of ice is formed and floats across the surface. This insulating layer of ice prevents loss of heat from the underlying water and also prevents the vertical movement or stirring of water by wind. Immediately below the ice layer, the temperature of the water falls to very close to 0°C, but the temperature increases gradually with depth until in few metres of depth it is 4°C. The rest of the water till the bottom is also at 4°C. Therefore, the lake doesnot freeze to the bottom in winter, and enters what is known as the "*Witner stagnation period*".

In spring : As the ice melts in spring and the surface layer of water warms up, it sinks and becomes replaced by cooler water found below it until the water temperature at all depths becomes 4°C, i.e. water attains the same density throughout the lake. Now the whole water mass starts to circulate or mix under the influence of the strong spring winds, a phenomenon known as the "*Spring turnover*".

In Summer *:* The surface water warms up above 4°C (The degree of maximum density), and becomes lighter and does not sink but floats upon the colder and denser water below. As the summer temperature continues to rise, the surface water becomes warmer, lighter and shows more resistance to sinking or mixing with the colder water below. Thus, a distinct stratification as regards water temperature and density occurs in the lake. Three main strata can then be noticed :

(a) *The epilimnion,* constitutes the upper stratum of warm water which is circulated by wind and, therefore, has an almost uniform high temperature.

(b) *The metalimnion (thermocline),* is a thin middle stratum in which the temperature drops quickly with depth (1-7°C per metre of depth).

(c) *The hypolimnion,* is the lowest stratum of cool water with a uniform temperature of about 4°C.

With the development of such thermal stratification in summer, water circulation stops in the hypolimnion. The water in that stratum remains stagnant through the summer and the lake thus enters upon what is known as "*Summer stagnation period*" or "Summer stratification period".

In Autumn : As the surface water is cooled again in autumn, it becomes heavier, sinks and becomes replaced by warmer water from below. The temperature of the water in the epilimnion is thus gradually lowered until it reaches that of the thermocline, then becomes the same as that of the hypolimnion. The whole mass of the water thus attains a uniform temperature of about 4°C and complete circulation of the water takes place from top to bottom, a phenomenon known as "*fall turnover*".

However, these changes in water temperature vary with the size and

depth of the lake. *Temperate lakes* are accordingly classified into 3 orders as follows :

1. *Lakes of the first order :* These are the largest and deepest lakes (generally over 90 metres in depth) in which a definite thermal stratification is produced in summer. The temperature of the bottom water remains at 4°C throughout the year. Two turnovers, in spring and autumn, are possible, but usually *no complete* circulation takesplace.

2. *Lakes of the second order :* These lakes (8-90 metres in depth) also develop thermal stratification in summer, but the temperature of the bottom water may rise little above 4°C. They undergo two distinct turnovers in spring and fall.

3. *Lakes of the third order :* These are the smallest lakes which do not usually develop thermal stratification in summer. The temperature at the bottom is similar to that at the surface, and complete circulation is more or less continuous throughout the year, except when the surface layer is frozen.

Conditions are different in *tropical lakes,* where the temperature of surface water seldom falls to 4°C. In these lakes, thermal stratification occurs throughout the greater part of the year. The surface water is not cooled enough to permit complete circulation except during the coldest part of the winter. Therefore, they have *one possible circulating period in winter,* or winter turnover, and their bottom water remains stagnant throughout the rest of the year. Tropical lakes are accordingly classified into :

1. *Lakes of the first order :* These lakes have the temperature of the bottom water at 4°C throughout the year, develop thermal stratification

during the greater part of the year, and may have one possible turnover in winter.

2. *Lakes of the second order :* These have the temperature of the bottom water not far from 4°C and development thermal stratification throughout the year except in winter where a distinct winter turnover occurs.

3. *Lakes of the third order :* These have the temperature of the bottom water similar to that at the surface, and complete circulatin is possible at all seasons.

In *Polar lakes* the temperature of surface water is always below 4°C. Therefore, complete circulatin is only possible during summer when the water is warmed to 4°C.

In *Ponds,* the temperature is often uniform at all depths except during summer (in temperature ponds) when they may show some thermal stratification. Daily and seasonal temperature changes are often greater in ponds than in lakes because of their smaller volume. Ice also forms earlier and lasts longer in ponds than in lakes. In some regions, because of decreased rainfall and continuous seepage or drainage, some ponds may be greatly diminished or dry up during the summer.

Annual Circulation Patterns and Lake Classification

The times when circulation occurs are, of course, periods of mixing. The noun *mixis* and its adjective *mictic* are used in compound words to categorize lakes according to annual circulation patterns.

I. *Amixis :* Some bodies of water never circulate. These are the amictic

lakes, permanently ice covered, that isolates the lake from the stirring effects of wind.

II. *Holomixis :* Holomixis is a typical lake phenomenon whereby wind-driven circulation mixes the entire lake. Overturn periods involve the total water mass.

(1) *Oligomictic lakes :* circulation periods in these lakes are unusual, irregular and short in duration. For example, Maggiore, a large Italian lake, circulates for a few weeks during February and March. This occurs, however, only once every 5 to 7 years during unusually cold and windy winters.

(2) *Monomictic lakes :* Monomixis is defined as one regular period of circulation occurring sometime within the year.

(3) *Dimictic lakes :* which have 2 mixing periods; the spring and fall overturns, each year.

(4) *Polymictic lakes :* lakes that have many or continuous mixing periods throughout the year. They are influenced more by the changing in daily temperature than by seasonal changes. Diurnally, the upper waters gain heat to stratify. Cold nights cool the upper layers to such an extent that the down currents destroy the stratification, and nocturnal circulation takes place until terminated by the following day's solar input.

III. *Meromixis :* Meromictic lakes circulate at times, but incompletely. In contrast to halomixis, the entire water mass does not participate in the mixing. A dense stratum of bottom water remains stagnant *(monimolimnion).* The upper layer; being much more dilute, is mixed ; by wind and shows seasonal changes, this is the *(mixolimnion).* Between them there is a zone where salinity increases rapidly with depth, the

(Chemocline). Based upon the manner by which solutes accumulate in the monimolimnion, the meromictic lakes classify to :

(1) *Biogenic meromixis :* In this kind there is an accumulation of substances derived from bacterial decay, diffusion from sediments, and from photosynthetic precipitation of carbonate. The waters are typically the *calcium bicarbonate* type.

(2) *Ectogenic meromixis :* Effective contrasts in density can be brought about by delivery of water to a lake from outside sources. This leads to what is termed ectogenic meromixis. The water can be delivered in 2 forms: first, as a dilute superficial layer that comes to lie above a preexisting saline body of water; or second, the outside source can be saline water that find its way to the bottom of a freshwater lake.

(3) *Crenogenic meromixis :* subsurface flows of saline, dense water into a basin, that contrast with a superficial freshwater influent. If equilibrium between the 2 types is established, the water becomes persistently stable.

Effects of temperature on aquatic orgnaisms

Animals with regard to their temperature relations fall into 2 categories :

1. Homoiothermic animals (warm-blooded or constant-temperature animals); have certain mechanisms by which they maintain the temperature of their bodies more or less constant and independent of the temperature of the surrounding medium. These includes only *birds* and *mammals*.

2. Poikilothermic animals (cold-blooded or variable-temperature animals) : whose body temperatures follow more or less closely that of the surrounding medium. Most aquatic animals are poikilothermic. Each of these cold-blooded animals has a maximum and a minimum survival temperature in between which life is possible, and beyond which conditions are lethal. These temperature limits differ for different species, different ages or stages in the life history, different sexes and different physiological conditions.

Some poikilothermic animals are restricted to a narrow temperature range and are known as *stenothermic* animals. Others are able to tolerate a wide range of temperature changes and are known as *eurythermic animals.* Somewhere between the minimal and maximal limits for these animals there is an optimum degree where life is at an optimum.

The temperature of the medium has a more or less direct effect on the metabolism of poikilothermic animals. Within the normal limits for any of these animals, rising temperatures increase the *metabolic rate* or reaction speed of many biological processes such as reproduction, development, respiration, heart beats, and rates of enzyme action and other physiological processes. There is an optimum temperature at which each life process goes on the fastest, and the most favourable temperature for survival may differ from the optimum value for growth, reproduction or other life processes.

An obvious example about the influence of temperature upon the rate of growth, reproduction and other physiological processes is what we find about the annual cycle of the copepod *Calanus.* The normal two monthes period required for life-cycle and egg maturation of *Calanus* could extend in the cold polar water throughout the whole year, and only one generation

of *Calanus* is produced in each year. In temperate waters, there are 2 generations of *Calanus* per year. Turning to warmer conditions, where the plant crop possibly provides better nourishment, we find 4 generations per year and sometimes an annual cycle of 5 or even 6, generations per year could results in tropical and subtropical regions.

Freezing may cause mechanical harm to organisms, rupturing the cell walls and stopping circulation. But animal tissues do not freeze at 0°C because the solutes in the body fluids cause a depression in their freezing point. Some animals have special adaptations to lower the freezing point of their tissues still further, and some can withstand actual freezing for short periods.

However, many animals are killed by low temperatures above the values at which their tissues freeze, and the lethal extreme varies greatly from species to species. If tissues do not freeze, why are these organisms killed then ? The answer is that most metabolic activities and chemical reactions are slowed down by lowering the temperature until they eventually stop. But, since the different vital processes are not equally affected by decreasing temperatures, they may be slowed down by different amounts until they become no more mutually adjusted, whence death occurs, even above the freezing point.

The lowest temperature at which the organism can live indefinitely in active state is called the "minimum effective temperature". Further, reduction in temperature causes the organism to go into *Chill choma* and if not warmed again before two long, the organism dies. The lowest temperature at which survival is possible is called "*the minimum survival temperature*". The same situation exists as regards maximum temperatures,

i.e. there is a ‘maximum effective temp.” and a “maximum survival temp.” for each species.

Adaptations to extreme temperatures

The effect of temperature on aquatic organisms is most pronounced in the surface layers because in deep waters the temperature is usually uniform. When the temperature rises too high or drops too low, plants and animals must either endure it or die. Living without special adaptations for meeting extreme temperatures may be very difficult on land, but is comparatively easier in aquatic environments.

During the course of evolution, many special structures have been developed by which organisms could endure exposure to extreme temperatures, such as :

1. Reduction of the amount of water in the animal’s body enables it to tolerate a wider range of temperature change.

2. Development of calcareous, siliceous or chitinous coverings also help enduring greater temperature extreme.

3. Certain animals and plants produce cysts, spores, gemmules, special eggs or seeds capable of resisting freezing and dryness.

4. Winter’s cold may be escaped in cold-blooded animals by winter dormancy or *hibernation* during which metabolism is reduced until favourable temperatures return. Summer dormancy is called *aestivation.*

5. Thermal migrations enables many animals and plants to escape extremely hot or cold situations. Many fish and other aquatic animals leave the shore in summer when the water becomes too warm. Other species

migrate into deeper water during winter to avoid temperatures near 0°C at the surface.

Temperature as a factor in distribution

Temperature as a factor in animal distributin has long been recognized and on the basis of this, the biosphere has been classified into distinct regions. It often acts as a limiting factor in the distribution of animals. As mentioned earlier, each species has a definite range of temperature tolerance beyond which the activities will not be normal. For example, *coral reefs* require a minimum temperature of 21°C for their existence. Hence, they are completely absent in the colder regions of the globe. They flourish in the warm waters of the tropics and subtropics. At the other extreme is the case of lamellibranch; *Portland arctica,* which is rarely met with in waters where the temperature is above 4°C. The desert animals on the other hand, are able to withstand very high temperature. In general, stenothermal animals are more restricted in distribution than eurythermal animals.

(2) Light

Light in aquatic environments :

Sunlight available for plants and animals in aquatic environments enters the water from air. But in the water, the light intensity is reduced far more rapidly with depth than in air. The amount of illumination within natural waters depends on several factors :

1. Intensity and duration of incident light. The intensity of

illumination in water is naturally affected by diurnal and seasonal variations in intensity and duration of sunlight.

2. Reflection at the surface and angular distribution in the water. At least 10% of the incident light is lost by reflection at the surface. The direct beam of sunlight is bent by refraction inside the water. The waves and ripples, which always exist in natural waters, tend to break up a considerable amount of the light passing into the water, thus further reducing the intensity of illumination in the water.

3. Scattering in the water. Suspended material, especially larger particles, reduce light penetration in the water because when light beams fall on these particles they become scattered in different directions instead of penetrating straight into the water.

4. Absorption. Water itself absorbs light at a very rapid rate compared to air, and different components of light are absorbed by different degrees. Thus, in passing down into pure water, the red component of light is absorbed most rapidly at a rate of 64.5% per metre, followed by arrange at a rate of 23.5% per metre, then yellow at 3.9%, violet at 1.63% green at 1.1% and blue at only 0.52% per metre. Very little ultra-violet light penetrates the water and nearly all infra-red is absorbed in the first metre. Thus, the blue light penetrates the farthest in water and at depths of 100 metres or more only blue light is found. The blue colour of water in large water bodies is due to this selective absorption of light components by water. The only component that is reflected upwards to the eye from deep waters is the blue one.

5. Transparency of the water and turbidity. The transparency of the water is also important in regulating the amount of light in the water. The

greatest extremes of turbidity occur in the running-water bodies due to the current. In these bodies, owing to the relatively low plankton production, turbidity is largely due to silt, detritus and other non-living material.

Lakes and ponds which are well stirred exhibit a uniform transparency from surface to bottom as in rivers. But in lakes the degree of transparency changes from season to season owing to differences in amount of stirring, discharge of muddy rivers into them and growth of plankton. These variations in transparency if added to variations in intensity of incident light and length of the day produce considerable seasonal fluctuations in light intensity in deep waters of lakes.

Vertical visibility, the Secchi disc, and the euphotic zone :

A disc, with a flat surface horizontal, is lowered into water on calibrated line , and the exact depth at which it disappears is noted. This is the Secchi disc *transparency*, expressed as a depth in meters, Z_{SD}. Obviously it is half the distance light travels to the disc and back up to the observer's eye. Usually the disc is 20cm in diameter, and the transparency should be determined between 10 am and 2 pm and observed off the shady side of the boat.

In the upper well-illuminated layers of water, photosynthesis prevails in daylight hours, where the phototrophic algae fix inorganic carbon to manufacture organic compounds. This zone called *euphotic* (or trophogenic) zone. In oceans it is up to 80 meters. Below this layer is the *disphotic* zone.

Effects of light on aquatic organisms

1. Light is essential to aquatic plant photosynthesis. Thus, it controls growth of aquatic plants which furnish directly or indirectly the carbohydrate and protein supply of aquatic animals. In spring, in temperate lakes, for example, as the days become longer, the phytoplankton increases enormously producing what is known as "*spring outburst of phytoplankton*".

2. Light enables animals to see and be seen in water so that they can secure food and escape enemies. The majority of larger species living in fresh water are insects with compound eyes and fish which are well adapted for seeing at low levels of illumination among weeds and on the bottom of streams.

3. Light plays an important role in orienting the direction of growth as well as the direction and speed of locomotion of aquatic plants and animals. Orientation of the direction of growth is known as "*phototropism*" and orientation of the direction of locomotion of motile organisms to light is known as "*phototaxis*". Light also controls the speed of locomotion, a phenomenon known as "*photokinesis*". Some animals increase the speed of locomotion with increasing light intensity even if they have no eyes.

4. Light also causes other characteristic responses which are vital to some organisms. Many animals have a preferred light intensity and move so as to keep within it. Many species of plankton and lower animals, for example, make periodic migrations in lakes, coming to the surface at night and descending to deep water during the day. This "*diurnal periodicity*" is largely controlled by light.

5. Pigmentation in animals may be directly related to light. Intense

radiation and excessive absorption of light by animal tissues is harmful. To avoid this, animals produce certain pigmentation to protect deep tissues. However, pigmentation of many animals also affords protection from enemies by matching the colour and pattern of the background.

Adaptations against excessive light

- To avoid excessive light, animals may simply move into the shade offered by shore plants and other material, burrow into the bottom mud or descend to deep waters. The 24-hour cycle in activity of certain animals and plankton mentioned above is a sort of adapatation to avoid excessive light in surface water during the day.
- Pigmentation, chitinous coverings, shells and other outer cases constructed of foreign materials provide protection to various degrees against direct sunlight.
- Another adaptation to avoid excessive light is to develop a transparent body. This adaptation, which has been evolved by most planktonic animals, enables them to endure high intensities of light in surface water.

Adapatations to the absence of light

The absence of light has resulted in the development of specialized tactile organs, special eyes and luminescent organs.

- The development of tactile organs is noticeable among deep sea forms. They take the form of long antennae in prawns and lobsters, and barbells and fin rays in the fishes.

- The presence of telescopic eyes or enlarged eyes is marked also among the deep sea fishes, which are meant for the efficient absorption of light.
- Development of bioluminescence (light emitted by living organisms) is another notable feature among the deep sea forms.
- The deep sea fishes exhibit sexual dimorphism where in the male is permanently attached to the female because it is difficult to find the mate due to the absence of light.

(3) Current

Velocity of Current :

The velocity of the current in a stream is one of its most important ecological characters. This velocity depends mainly on the volume of the water and on the slope and roughness of the stream bed. The current attains its greatest velocity in greater slopes and abrupt waterfalls and reaches its minimum velocity in situations where for long distances the slope of the stream is negligible, and extremes of current velocity may occur within a single stream or river.

The velocity of the current is also not uniform in all parts of a cross section of the channel. It diminishes near the bottom and the sides of the channel due to frictional effects. The maximum velocity is usually found near the middle of the channel, somewhere within the first 1/3 of the depth. Velocity then decreases considerably with depth. For this reason, smaller animals tend to remain on he bottom of the stream among stones and aquatic plants where the water flow is the least. Fishes are often seen

motionless near the bottom also because they can maintain their position there with the least muscular effort.

Effects of current on stream organisms

The current affects plants and animal life in streams in different ways:

(1) The current tends to wash away all organisms other than those which are rooted, capable of taking shelter or are powerful swimmers. Planktonic organisms are thus carried out from rivers to the sea or lakes and this may explain why streams are relatively poor in plankton. Even rooted plants ae relatively few in running- water bodies, and may be scarce in swift streams. Instead, filametous algae may be found growing on rocks on the bottom and constitute the basic food material for stream fauna.

(2) The current causes continuous erosion of the stream bed, with periodic accumulation of silt in the vicinity of obstructions such as larger stones and rocks. This affects the distribution of aquatic organisms living on the stream bed.

(3) The continuous motion of water keeps it in a state of almost permanent saturation with air or oxygen. Moreover, it makes the whole water mass uniform in pH, temperature, and content of dissolved substances and nutritive material, especially downstream. All these are important factors directly affecting the life of stream organisms.

(4) In swift streams, both flooding and drought may kill whole populations. However, repopulation is relatively rapid since pools in the course of a stream may provide refuge for many organisms during periods of flooding or drought.

Adaptations to swift current

Organisms inhabiting streams and rivers usually show a variety of adaptations in structure or habit to maintain their position against the force of the current:

(1) Some organisms develop hooks, suckers, attachment threads or gripping appendages and surfaces for clinging to the substratum. Snails, for example, attach to the substratum by flat adherent surfaces covered with a mucous secretion, and various aquatic insects and insect larvae cling with modified appendages to rocks with their heads pointing towards the current.

(2) Primitive forms become either anchored to the substratum throughout their life, as in case of sponges, or become epizoic on larger animals, attaching to their larger bodies.

(3) Developing a small body, small appendages and a streamlined form are other kinds of adaptations which enable animals to resist swift currents and move more rapidly in the water.

(4) The ability for vigorous swimming enables certain fish to dart from one sheltered spot or rock to another against the current.

(5) The habit of taking shelter behind and below rocks also enables animals to endure swift currents. Most species in swift streams remain near the bottom and develop this habit.

(6) Fish and most bottom dwelling animals are automatically oriented to face upstream. Their organs of attachment or their pectoral fins are located anteriorly and the current acts on their long posterior body so as to turn the animal and make it

face upstream. Besides resisting the current, this orientation which is referred to as *positive rheotaxis,* has the advantages of enabling the animal to expel the respiratory water from the gills and the excretory products more easily, and to look in the direction from which food is most likely to come.

B. Chemical Factors

(1) Oxygen

Oxygen is needed by almost all organisms to make available the energy contained in their organic food material. The majority of plants and animals use free O_2 from air or dissolved O_2 from water and are described as "aerobic organisms". "Anaerobic organisms" on the other hand, get their energy by partial decomposition of organic matter without using free O_2.

The principal sources of Oxygen in natural waters are :

(1) Oxygen absorbed directly from air through the exposed water surface. Agitation of the water by waves and currents helps to dissolve more of that oxygen.

(2) The oxygen released beneath the water surface by photosynthesis of green aquatic plants. As these plants grow, they produce more oxygen than they consume.

The principal factors which eliminate oxygen from natural waters are:

1. Respiration of aerobic aquatic animals and plants.
2. Oxidation or decomposition of organic matter and various bottom deposits in the water, mainly by bacteria.
3. Bubbling of other gases in the water, such as CO_2 and methane, which accumulate at the bottom.

4. The inflowing of ground water which is usually very low in dissolved oxygen.
5. Rising of the water temperature, as happening in summer, reduces the capacity of water to hold oxygen and some of this gas is therefore released in the atmosphere.

In *streams and rivers* the water is usually permanently saturated with oxygen all year round because of the continuous current. But in standing water bodies, there is always an oxygen gradient from top to bottom, i.e. the oxygen concentration varies at different depths, and is subject to considerable seasonal fluctuations.

In lakes, at times of circulation-during the spring and autumnal overturns- oxygen is distributed more or less uniformly from top to bottom.

If one should plot a curve based on oxygen values in relation to depth, the line would be nearly straight. This is an *orthograde curve*. When thermal stratification occurs during summer months, the tropholytic (aphotic) zone becomes isolated from the upper waters. Now oxygen begins to be consumed there : (a) In *oligotrophic* lakes; with large hypolimnion and little production of organic matter in the epilimnion above, the demands on the oxygen in the tropholytic zone are so slight that it shows no appreciable decline. The summer time oxygen profile, therefore, is ***Orthograde*** despite thermal stratification. (b) In *eutrophic* lakes; great quantities of dead and dying organic matter effect a severe decrease on the Oxygen in hypolimnion waters. The vertical curve is now termed ***Clinograde***. (c) In *some lakes* unusual oxygen profiles are observed. One of these shows a maximum in the thermocline. The maximum may be well above saturation. This **is *positive heterograde***

distribution. This may be due to the presence of some blue-green algae thrive in the dim light of the metalimnion; much of O_2 they produce accumulates because photosynthesis exceeds respiration.

In other lakes, it is noticed oxygen minima within vertical profiles ***(negative heterograde).*** Some explained this by respiration of a marked concentration of nonmigrating animals or by decaying organic matters.

In winter, if the lake is covered with ice, there may be a winter stagnation period in which the hypolimnion becomes again deficient in Oxygen.

Ecological effects of oxygen deficiency

The summer depletion of the hypolimnion from oxygen causes many aquatic animals to *migrate* away from this region or to adopt some kind of *temporary anaerobic existence.* Some fish, crustaceans and free moving bottom animals undergo seasonale migrations, leaving the hypolimnion to the epilimnion as summer stagnation begins.

However, many animals and plants with no efficient respiratory adaptations or means to escape oxygen deficiency die off in large numbers during stagnation periods.

In aquatic habitats which are permanently devoid of oxygen no aerobic organisms can live, such as in the very deep waters of some lakes and in the Black sea. The bottom fauna of these habitats consists chiefly of anaerobic protozoa and bacteria.

Respiratory adaptations in aquatic organisms

Most land organisms find enough Oxygen in their habitat, and the majority of marine organisms are so adapted that the amount of oxygen in the sea water meets their respiratory needs. But in freshwater habitats, the oxygen supply may vary from supersaturation to total exhaustion. Inhabitants of such environments display various respiratory adaptations to obtain necessary oxygen, some of which are :

(1) Some animals, such as aquatic pulmonate snails, breath *atmospheric* oxygen in spite of living in the water. They have lung cavities and rise to the surface at intervals to renew their oxygen supply.

(2) Aquatic insects show several other adaptations. Many water bugs and beetles *rise to the surface periodically* to take an *air bubble* beneath their wings or their ventral body surface. Others store considerable amounts of oxygen and air in their respiratory tracheae to breathe for long periods under water. Still others, like mosquito larvae, possess breathing tubes which they extend to the surface to get atmospheric air. Tracheal gills, plates or filaments are also developed in many insects to increase the surface area available for oxygen absorption.

(3) Some annelids and snails possess haemoglobin in their blood which is of greater capacity and efficiency to absorb Oxygen at low oxygen pressure.

(4) Some bottom-dwelling protozoa, annelids, molluscs and insects can survive actual *anaerobic conditions* for days or

weeks. They do so by creating an "oxygen debt". i.e. they accumulate lactic acid and other catabolic products of anaerobic respiration in their bodies until conditions permit oxidation of these products. Other organisms become temporarily dormant so that their metabolism is reduced and they can withstand oxygen deficiency for varying periods.

(5) Some animals are able to bare into the stems and roots of emergent plants and obtain oxygen from their internal air spaces.

(2) Carbon Dioxide (pH and alkalinity)

The amount of carbon dioxide present in the medium is important for aquatic organisms just as it is for terrestrial ones. Carbon dioxide dissolves easily in water, but since its concentration in the atmosphere is very low, water in equilibrium with air may hold only 0.5cc/litre of free CO_2 at 0°C. However, the total CO_2 found in natural waters is actually more than that because additional amounts are found in the form of carbonates and bicarbonates.

Unlike Oxygen, CO_2 combines chemically with water to form carbonic acid (H_2CO_3). This acid reacts with available alkalis to form half-bound carbonates (i.e. bicarbonates) and bound or fixed carbonates as follows :

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \rightleftharpoons H^+ + CO_3^=$$

$$CO_3^= + Ca^{++} \rightleftharpoons CaCO_3\ (ppt) \downarrow$$

The amount of free CO_2 gas found in simple solution and that in the

form of carbonic acid constitute what we refer to as the "*free carbon dioxide*" in water, while the amount of CO_2 found in the form of bicarbonates and carbonates is the "*combined carbon dioxide*".

It is clear from the above equation that when carbonic acid dissociates in water it releases *hydrogen ions* (H^+) and these affect the pH of the water. Therefore, if CO_2 is added to the water (as by respiration) more carbonic acid is produced, and as this acid dissociates free H^+ ions are formed, thus the *pH is lowered.* Consequently, more HCO_3^- ions are formed through the reaction of the excess H^+ ions with $CO_3^=$ ions. The reverse situation occurs when CO_2 is withdrawn from the water (as by photosynthesis), more CO_3^{--} (or Ca CO_3) is formed.

In nearly neutral waters (pH 7.0), most of the carbon dioxide will be present as *bicarbonates.* In alkaline water with higher pH values, more CO_2 is present as carbonate ions ($CO_3^=$), and in acid water with lower pH values, more CO_2 is present in the free condition. Therefore, any factor that affects the CO_2 equilibrium in it, and conversely any addition or removal of CO_2 from the water affects its pH.

The principal sources of CO_2 in natural waters are :

1. The CO_2 absorbed directly from the atmosphere.
2. Rainwater is charged with CO_2 as it falls towards earth.
3. Runoff; water pass through organic soil may become further charged with products of decomposition and later enter a stream or lake introducing gaseous CO_2 in solution.
4. Respiration of aquatic animals and plants.
5. Decomposition of organic matter by micro-organisms.

6. Inflowing ground water.
7. Action of acids on carbonates and bicarbonates in the water.

$$H_2CO_3 + CaCO_3 \rightleftharpoons \underset{\text{soluble}}{Ca(HCO_3)_2} \rightleftharpoons CO_2 + H_2O + CaCO_3$$

The principal factors which eliminate CO_2 from water are :

1. Photosynthesis of green aquatic plants.
2. Deposition of carbonates on the bottom or in the shells and skeletons of aquatic animals.

Ecological effects of CO_2 in aquatic environments :

1. The most important effect of CO_2 in aquatic environments is the part it plays in *photosynthesis* of green plants. Plants living in waters with high pH must survive on the small amounts available of free CO_2 or else they must use the CO_2 existing in combined form. Many pond plants have been found to *absorb the HCO_3^-* ions and to use them in photosynthesis.
2. Abundance of CO_2 in water speeds the *rates of growth* and of some metabolic processes of certain bacteria, protozoa and many other animals, but other processes are inhibited by excess CO_2.
3. The concentration of CO_2 in water influences its equilibrium in *the blood* of aquatic organisms. An increase in the CO_2 in the blood causes a *decrease in the O_2 affinity* of the vertebrate haemoglobins and invertebrate haemocyanins.
4. Abundance of CO_2 in water evokes *certain responses* in aquatic animals. Some fish migrate upstream or to locatities near the shore for spawning in suitable places with less CO_2.

Alkalinity :

Very closely associated with the forms of CO_2 is the so-called alkalinity of the water. Alkalinity is customarily expressed in terms of equivalent *bicarbonate* or *carbonate,* although other ions could contribute to it. Additional names for alkalinity are *acid-combining strength,* acid capacity or power to combine with acid.

Ordinarily , alkalinity is an index to the nature of the rocks within a drainage basin and it is commonly results from CO_2 and water attacking sedimentary carbonate rocks and dissolving out some of the carbonate to form bicarbonate solutions.

Origin of Freshwater Animals

Evidence from fossils indicate that the first animals which lived on our planet were largely or wholly marine. Land and freshwater habitats were populated later, by repeated invasions from oceans. In other words, life in fresh water is most probably not original but derived, either directly from the sea or indirectly from land. Thus, freshwater animals of today are believed to have evolved in one of the following ways :

1. Either by slowly migrating up rivers from the sea, or by moving into brackish water basins and swamps near the sea shores. Some of these basins were probably isolated later and cut off from the sea. The water in them became gradually fresh as a result of being continuously supplied with rain and river waters from the surrounding land. The animals inhibating these basins were later directly transported from one water body into another, either by active dispersal, by wind action, or on the feet of birds and other wandering animals.

2. Another method could be by movement from land habitats. That is some animals which have left the sea to land tended to go back into water. Evidence for this can be seen in some animals which live in fresh water but continue to breathe atmospheric air. Such animals, although living “in” water are not actually “of” it, e.g. freshwater pulmonate snails. Other animals have later modified their means of respiration. Thus some aquatic insects breathe through respiratory tracheae like their land ancestors, but many other insects, particularly during their larval stages, have acquired tracheal gills and respire directly from water.

Regions Limnology

Lake Qarun

Lake Qarun is one of three enclosed inland lake in Egypt. It covers 53,000 feddans and is located in the Western desert in Fayoum depression, 87 Kilometers to the south west of Cairo. It represents the remnant of the ancient, pre-historic, freshwater lake Moeries. It was directly connected to the Nile forming a natural reservoir for the flood water, and, therefore, inhabited during that time by freshwater fauna and flora derived from the Nile.

Based upon geolgocial and archeological evidences canto-Thompson and Gardiner (1929) concluded that a lake of 63 meters depth, which they called the (Neolithic), was present in a level of about 59 meters above the present lake level, before the main Fayoum settlement was established. They assumed that this falling of water in its final stages gave rise to lake Moeries at not more than 46 meters above the present level of lake Qarun (i.e. nearly at the sea level).

Ball (1939), speculating the way in which Lake Moeries was

transformed to lake Qarun, thought that lake Moeries became disconnected from the Nile which caused the lake surface to fall below the level of the Nile. Also, water evaporation might cause the lake surface to sink to lower levels and thus reaching to the lake Qarun level and leaving a large additional area of land for cultivation.

Because the lake has been disconnected from the Nile river and became a drainage reservoir for the cultivated lands of Fayoum Province, the amount of freshwater which reaches it, has been greatly reduced. The lake receives only brackish drainage water (salinity of about 1.25%o), annually estimated to be as much as 390 million cubic meters which conveyed an average of about 430,000 tons of salt to the lake every year. A volume of water nearly equal to that of the influx of drainage water is lost annually from the lake through evaporation while the dissolved salts are left in the water of the lake.

As a result, the salinity of the water of the lake increases continuously as time passes. The earliest record of the salinity of water of lake Qarun, goes back to 1901; it was about 13.4%o. In 1920, it was about 18.0%o. In 1934, was about 23.4%o. In 1955 was about 30.1%o. Nowadays, the salivity varies according to water level and temperature between 30.9% in winter and 34.5%o in early Autumn.

The fish fauna of the lake was drastically affected by the salinity increase. With the exception of *Tilapia zillii,* all fishes of freshwater origin have gradually disappeared from the lake fauna. Among these fishes were *Tilapia nilotica, Clarias lazera, lates niloticus* and *Labeo niloticus.* In 1936, the last remnance of freshwater fishes was recorded, and the cichlid fish *Tilapia zilli* constituted about 80-95% of the total catch.

To compensate the loss of the freshwater fishes, Alexandria Institute

of Hydrobiology and Fisheries began acclimatization of some marine fishes in the lake. Fry of mullets, mainly *Mugil celphalus, M. capito* and *M. salinus* were transplanted in 1928. The introduction was so successful that in 1935 the mullet production reached 341.7 kg., i.e. 21% of the total catch. *Solea vulgaris* was another marine fish that had been introduced into the lake from the Mediterranean sea in 1938, and by early 1949 its commercial catch was about 18% of the total production.

Phytoplankton and zooplankton organisms are of marine origin and are known from the Mediterranean waters at Alexandria. They have been introduced to the lake through the process of fish restocking and they found the new environment suitable for them.

The biological productivity of the lake is very high (eutrophic type) and the annual fish production is about 1363 tons.

Bathymetric chart of lake Qarun

(ℓ) Maximum length (from east towest) : 40 km.

(b) Mean breadth : 5.7 km.

(A) Surface area : 235 km^2 (about 53,000 Feddans)

(V) volume : 1.054 Km^3 at 4.35 m below the mean sea level.

(z) Mean depth : 4.2 m = Zc (cryptodepression).

(Zm) Maximum depth : 8.5 m.